Solar Module Monitoring Expert System for PV System Model Design

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Abstract: **This paper presents an application of knowledge-based expert system (ES) for evaluating PV model power generation system. The deployment of PV system needs a strategy in order to get the maximum result. The strategy must be according to certain criteria. The performance of a PV system depends on the environmental factors such as irradiation and cell temperature. For the operation planning of power systems, the prediction of the power generation is inevitable for the PV systems. For this purpose, irradiation, temperature and wind speed are utilized as the input information in real condition. The output is to predict maximum performance of PV system power generation under the real condition by those environmental factors.The final result of the developed expert system will be a complete model design of PV system including the performance of the proposed system, cost analysis and deployment strategy.**

Index terms- **PV module, expert system, irradiation, temperature, wind speed, photovoltaic system, monitoring.**

I. Introduction

The world wide demand for solar electric power systems has grown steadily over the last 20 years. The need for reliable and low cost electric power in isolated areas of the world is the primary force driving the world wide photovoltaic (PV) industry. For a large number of applications, PV technology is simply the least-cost option. It is important to determine the correct system size, in terms of both peak output and overall annual output, in order to ensure acceptable operation at minimum cost. If the system is too large, it will be more expensive than necessary without increasing performance levels substantially and therefore the system will be less cost-effective than it could be. However, if too small a system is installed, the availability of the system will be low and the customer will be dissatisfied with the equipment. Again, the cost-effectiveness is reduced. Hence, the idea of providing electricity to an area is tempered first with study of resources availability, socio-economic situation, electricity demand, environmental impact, market-based and ability, pay-back period and willingness of the end users to pay for the electricity. All of these criteria have to be considered for realizing the PV power supply development. The successful integration of PV system requires careful consideration at all design stages to ensure that the selected technologies are well suited to the application. In order to accurately predict the electrical output of the systems, the panel's electrical response to various parameters must be known. For example, the model advocated by King [8] requires the following parameters:

1. Influence of solar angle of incidence
2. Influence of solar spectrum
3. Temperature coefficient for the open circuit voltage and maximum power voltage
4. Temperature coefficient for the short circuit current and the maximum power current
5. Module operating temperature as a function of ambient temperature, wind velocity and solar radiation.

Additionally, energy industries world-wide are undergoing significant transformation, in general towards greater competition. A move towards competitive markets in the electricity industry is seeing the emergence of various tariff structures that may directly affect the economic returns of PV installation. The high level of interest in PV, the variety of potential operating environments and the emergence of new tariff regimes has created a need to accurately model the performance of a range of PV product. The need arises from the perspective of PV product designers as well as group considering investments of PV. Of primary importance is the potential energy yield and economic return in particular installations. This paper describes a PV simulation tool which attempts to capture significant aspect of system performance. The tool uses real condition weather data such as ambient temperature, solar radiation and also the solar panel performance test according to the available resources.

II. Data Acquisition and Analysis

To investigate the fundamental characteristics of the PV modules, the long term measurement is on going. Table 1 indicates the specification of PV module used for the measurements. The modules are set with the slop of 35 to 90 degrees. The I-V characteristics, power, voltage, and current are measured every an hour. Fig 1 and 2 show the samples data collected from a solar panel according to the panel orientation west and east of voltage output for a day from 8 am to 7 pm.

Table 1. Specification of PV module.

Max. power (Pmax)	75 W
Short circuit current	4.75 A
Open circuit voltage	21.4 V
Optimum operating current	4.45 A
Optimum operating voltage	17 V
Module size	20.9" X 46.8"

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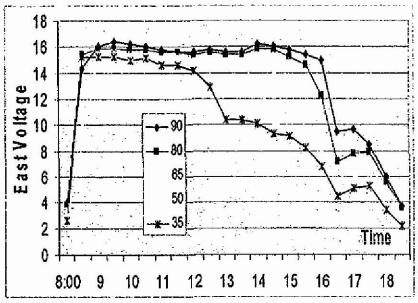

Fig. 1. Sample data of voltage output for west orientation panel.

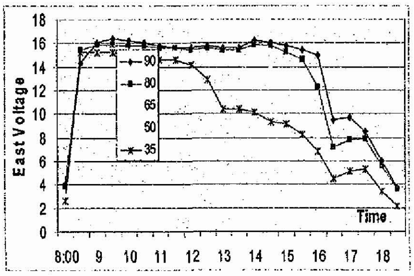

Fig. 2. Sample data of voltage output for east orientation panel.

In addition the environmental factors, such as the irradiation, temperature, humidity and wind velocity are measured at the same interval by using personal computer based measurement system. In Fig. 3 and 4, data of ambient temperature and solar radiation were collected for every half an hour everyday.

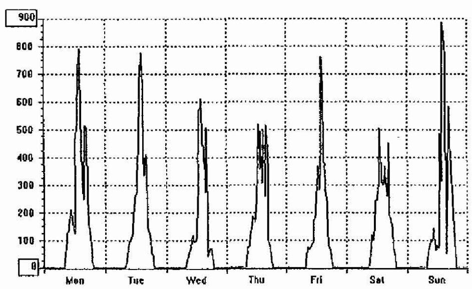

Fig. 3. Sample data of solar radiation for a week.

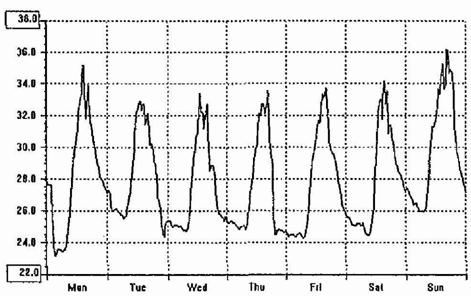

Fig. 4. Sample data of ambient temperature for a week.

The earth rotates about its axis every twenty-four hours, therefore any location faced to the sun about 12 hours a day. Hence, we assume that the solar energy available 12 hours per day. In peninsular Malaysia, the average solar insulation is 4.5 kWh per meter square per day. Considering the available solar radiation, module area and angle, these parameters can derive total solar energy per day as in Equation (1).

$$S_{ep} = I_{Total} \times S \times [\sin(\alpha)\sin(\beta) + 1] \qquad (1)$$

where: - S_{ep} is solar energy per day
- I_{Total} is global solar radiation
- S is area of the PV module
- α is duration available for solar energy conversion and varies between $0° < \alpha < 180°$, $15°$ per hour and also is a sun trajectory from the east and west.
- β is a degree of PV module's angle, it varies from $0°$ of the negative direction of zenith to $90°$ at co-ordination of North and South, east and west orientation.

The amount of energy produced by a PV device depends not only on available solar energy but also on how well the device converts sunlight to the electrical energy i.e. the efficiency of the cell or module used. The conversion efficiency can be measured by the equation below:

$$\eta = \frac{P_{max}}{S_{rad} \times Area} \times 100 \qquad (2)$$

where P_{max} is the maximum output power (kWh)
S_{rad} is the solar radiation intensity (kWh/m^2)
Area is the total area of the cell or module (m^2)

III. EXPERT SYSTEM DEVELOPMENT

The basic configuration of the system is shown in block diagram in Fig. 5. There are two parts in the system development, hardware and software. In hardware part, all the data are collected by the microsystem before send to the monitoring pc. The microsystem of data acquisition as related to photovoltaic systems gives comprehensive support to the design of a PV system for general users. The system is not only limited to collecting data but the system also analyze and remedy the performance of PV systems.

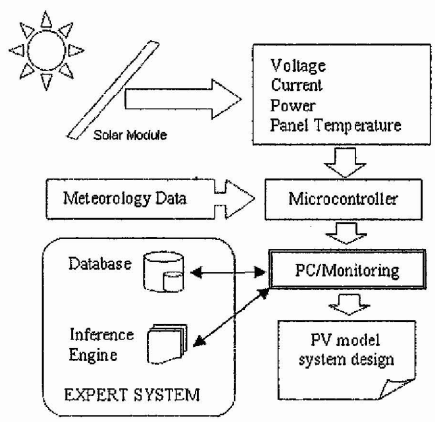

Fig. 5. System's block diagram.

The microsystem architecture uses a microcontroller to control and monitor the data acquisition as represented in Fig. 6. The analog part is composed essentially of one adaptation and an analog multiplexer allowing the acquisition of many meteorological parameters and the parameters related to the PV system. The numerical part of microsystem allows the transfer of data between the analog-to-digital converter (ADC) and the data bus. The treatment of data is in real time in the microsystem and the transfer of data to the pc is carried out through a bidirectional serial port using an RS232 protocol.

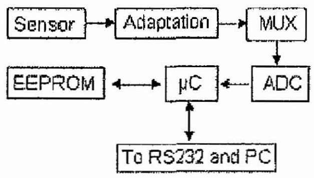

Fig. 6. Microsystem architecture.

The data are collected from real weather condition i.e. solar radiation, ambient temperature and humidity. At the same time, the data also collected from PV module where all the output from PV module such voltage, current and power are recorded. These two major parameters (weather condition and PV module monitoring) will be analyzed by ES to evaluate the best PV system model for that location.

In software section, the tool uses a structured navigating path to enable user to specify about the location in detail and energy demand for that location. As can be seen in Fig. 7, the location information window will come out when the user select the location info at tree view box. All required information must be inserting here.

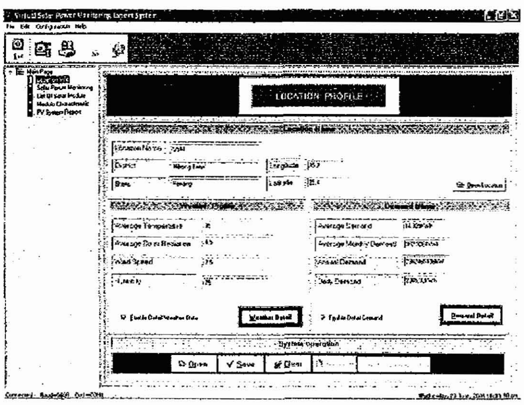

Fig.7. Location information windows.

To make a user friendly, the tool has been designed as simple as possible for the user to put the data. For evaluation and analysis of the performance of the proposed PV system model, the user has two choices to do, either for step by step analysis or let the ES to find the best way for PV deployment strategy. So, this tool makes easier for the user especially for those who do not know much about PV design.

This program consist all of the solar panel's technologies and its characteristic as an example can be seen in Fig. 8. All the solar panel technologies available in market were stored in data base including its prices and supplier address. More than one hundred panels with different characteristic are available in the tool to make user can find the best choice for their system at lowest cost. This module data can be added or edited by user to add new module technology if not available in database.

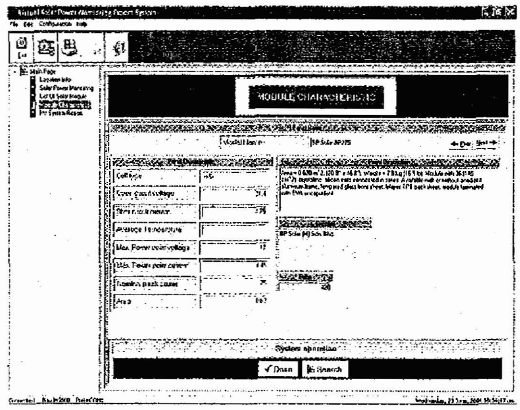

Fig. 8. Specification of a photovoltaic module.

The ES has been established to assist practitioners to identify the demand, supply technologies, and to ensure the effective operation of these technologies when deployed together. It also considered the economic factor for the whole system including pay-back period when using solar compared to conventional supply. This tool will help the end user estimate the size and cost of a PV system. This program will automatically perform the mathematical calculations required for system sizing, greatly reducing the time required to size PV systems. The final model will give the complete design of PV system with the right number of PV modules and configuration, number of series and parallel connection for a PV system. Doing a life cycle cost analysis (LCC) gives the total cost of the PV system. There are two reasons to do an LCC analysis i.e. to compare different power supply options and determine the most cost effective system design. So, in the PV system design, the final result output will show the total cost benefit of the system and its pay back period to recover the investment.

IV. CONCLUSION

The effectiveness of the tools is confirmed through by several design examples. Building photovoltaic power supply replace conventional electricity supply have many advantages for long period of time either for large scale of photovoltaic power supply or for a single building or house. This project allows energy managers, planners and designers to appraise the potential for PV system deployment at an early stage in the design process of solar power supply. Site specific technologies can be identified and their installation capacity established. It also will increase public awareness about the benefit of photovoltaic power generation. The tool also provides the complete PV system design and its performance. So the user can measure values for actual systems.

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VI. BIBLIOGRAPHIES

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